Interactive Multimedia and Learning: Realizing the Benefits

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SUMMARY

Many people argue that interactive multimedia has the potential to create high quality learning environments which actively engage the learner, thereby promoting deep learning. However there is growing evidence that the potential of interactive multimedia is not being fulfilled. This paper argues that if we are to design effective interactive learning application then a user-centred approach to their design should be taken. This approach should be based on general human-computer interaction principles as well as educational theory. The paper starts with an overview of the learning process. Consideration is then given to how the key elements of interactive multimedia (multiple media, user control over the delivery of information, and interactivity) can be used to enhance that process, with the emphasis being on promoting deep learning. The paper concludes by giving suggestions for future work.

INTRODUCTION

Multimedia has the potential to create high quality learning environments. The key elements of multiple media, user control over the delivery of information, and interactivity can be used to enhance the learning process through creating integrated learning environments. Explanation can be combined with illustrative examples, online assessment with feedback and the user can be provided with opportunities to practice and experiment. A range of media elements can be used to convey a given message and the user can study at a time and place convenient to them, taking as long or as little as they need.

However, the very richness and complexity of interactive multimedia can lead to problems if the needs of the learner are not given careful consideration. As Norman (1988) points out, for any design to be successful, in terms of developing usable and understandable products, then that design must be based on the needs and interests of the users and be informed by an understanding of their limitations and capabilities. In the context of interactive multimedia learning applications this involves consideration of both human-computer interaction and learning theory.

Failure to do so can lead to poorly designed applications that do not meet the needs of learners. Rogers and Scaife (1997) point out many multimedia applications fail to live up the developers' claims of providing enhanced learning environments. They found that learners often focus on the dynamic elements, for example surfing through video clips, rather than engaging with the material. Aldrich *et al*. (1998) report that learning applications often contain interactions which are largely gratuitous, doing little to support effective learning.

To ensure that multimedia-learning applications realize their potential it is necessary to stand back and re-examine the key features of multimedia and how they can be used to enhance learning. This can best be achieved through fuller consideration of the learning process itself and by exploring the benefits that interactive multimedia can bring to this. Possible pitfalls must also be identified.

The remainder of this paper is divided into three main sections (Learning Considerations, Interactive Multimedia and Learning and Integration into the Curriculum) followed by conclusions. The first section

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starts with an overview of the learning process. Emphasis is placed on the need to involve the learner in activity when promoting deep learning; techniques to do this are explored. The second section provides a critical analysis of how the key elements of interactive multimedia (multiple media, user control over delivery and interactivity) can be used to promote deep learning. Different techniques for involving the learner are explored. Ways in which individual learning preferences can be supported are also addressed. In the third section advice is given on how best to integrate interactive multimedia into the curriculum. The paper concludes by giving suggestions for future work.

LEARNING CONSIDERATIONS

Instructional principles and practice have moved away from an emphasis on learning as reproducing knowledge to learning as transforming knowledge, from rote learning to meaningful learning. The Dearing report (1997) highlighted the need to improve the quality of learning and advocated a more learner-centred approach in which the various needs and circumstances of learners are recognized. The MacFarlane report (CSUP, 1992) noted that, in the context of higher education, learners are now not only required to acquire extensive knowledge or facts about their subject area but that they should also be able to exhibit critical and independent thinking about the subject matter. Moreover they are also expected to develop transferable skills, such as communication, intra-personal and problem-solving skills.

Entwistle *et al*. (1992) categorizes these two contrasting approaches to learning (learning as reproducing knowledge and learning as transforming knowledge), as surface and deep learning. Surface learning is associated with a learner being able simply to reproduce the information as originally presented. Deep learning is associated with not only acquiring the information but also understanding it through relating it to previous knowledge and experience. The latter approach requires active involvement on the part of learner. Laurillard (1993) favours a similar approach whereby learning is placed in the context of concrete experiences and activities and where the learners take an active role in the learning process.

Educational theorists and practitioners, in developing models for instructional design that promote deep learning, have drawn upon the work of psychologists. Mayes (1995) argues that three of the most important research findings from cognitive psychology are that:

- learning is a by-product of understanding;
- understanding occurs best through performing tasks;
- learning is largely social in origin.

Ausubel *et al*. (1978) argue that new subject matter can only be learned if it can be related in some manner to previously stored knowledge and advocate using anchoring devices or advanced organizers. These can help bridge the gap between what learners already know and what they need to know if they are to successfully learn the task in hand, an approach which has parallels with both Rumelhart and Norman's (1981) schema acquisition model and Piaget's (1972) theory of equilibration.

Mayes (1995) also identifies the need to put the new information into context and for the learner to apply it in practise, emphasizing that true understanding will not occur without a cycle of action, feedback and reflection. He believes that discussion with fellow learners and instructors can promote the process of feedback and reflection. Fowler and Mayes (2000) characterize learning as an iterative process and have developed a model which sees learning as a process of on-going refinement of conceptualization–construction–identification, with dialogue playing a central role in each stage.

Knowledge is first conceptualized, abstracted and then interpreted and considered by the learner. The learner's conceptions of this new knowledge then need to be applied and tested in meaningful activities, which may lead to initial beliefs being verified or contradicted. In either case the outcome needs to be considered through internal or external dialogue, which in turn leads to the new knowledge either being assimilated into existing schemata or existing schemata being adapted to incorporate the new knowledge. If this process is successful then not only has the learner acquired the new material but has done so in a meaningful manner. The learner is now ready to progress, to build upon what they have learnt and to develop an even deeper level of understanding; the cycle starts again.

Contextualization and conceptualization can be aided by direct involvement of a learner in applying new knowledge in a meaningful manner. Deep learning requires a learner's active engagement with the new material. Active engagement has many facets: learning by doing, through taking the new knowledge and applying it in practise, is one aspect. Active learning is more than simply doing something; it also involves

active reflection on the part of the learner (Piaget, 1972). This not only requires reflection on what is being presented, by relating it to their previous experience, but also on their experience in applying the new knowledge being presented, thereby assimilating the new material into existing schema or modifying them through accommodation. Learning has a social aspect and the activity of reflection can be strengthened through discussion (Vygotsky, 1962, 1978).

Learning is a complex process with many different factors to be considered. However, from an analysis of learning theory it is possible to identify conditions that are more likely to promote deep learning. These include supporting or encouraging the learner in relating new material to existing knowledge, using or applying the new material and clarifying their ideas through reflection and discussion with others. Having identified these conditions it is now possible to explore how interactive multimedia can be exploited to benefits learners.

INTERACTIVE MULTIMEDIA AND LEARNING

Multiple media

Multimedia enables designers to choose from a range of media elements to convey a particular message, whether that is text to display simple instructions or moving images to represent a process. If potential problems, such as memory overload, divided attention and disorientation are to be prevented then human psychological limitations, such as memory load, perception and attention must be considered when designing interfaces. Guidance is required for media presentation (how much information is displayed on screen and how it can best be presented) and media selection (which media should be used to convey a given message).

Work has already been done in developing general guidelines for the design of screen layout, particularly with respect to text and graphics. Boyle (1997) provides an overview with an emphasis on presentation design for educational multimedia. Clark (1995), McAteer and Shaw (1995), Sutcliffe (1995), Faraday and Sutcliffe (1997) and Vossen *et al*. (1997) also provide guidelines on how to present sound, video and animation, as well as text and graphics. The International Organization for Standardization's emerging standard, 'multimedia user interface design – ergonomic requirements for human-centred multimedia interfaces (ISO 14915)' is a useful source of general advice.

Media presentation is only one aspect of screen design, media selection must also be considered. ISO 14915 has a section on media selection and media combination, which will explain how individual media elements can be used and how they can be combined. Sutcliffe and Faraday (1994) address the issue of selection and attentional design, as well as persistence of information, attention and concurrence in presentation, for task-related multimedia interfaces. They propose guidelines for media selection and presentation scripting in the forms of selection rules and validation rules, for example visual media resources can be used to illustrate spatial relationships. These guidelines can be adapted for use when developing interactive multimedia applications for educational purposes and assist in selecting media components and delivery planning. McAteer and Shaw (1995) give general guidance on the use of different media from an educational perspective.

Assuming that the content lends itself to being presented in more than one medium, a given piece of information can be delivered using more than one media element. For example a picture can be used to illustrate a text-based description, or audio employed to summarize other information on screen. Multimedia can support multiple representations of the same piece of information in a variety of formats. This has several implications for learning.

Learners are not a homogenous group. Some learners prefer to represent information verbally when thinking (verbalizers) and others visually (imagers). Riding and Douglas (1993) found that learning performance was affected if information was not presented in a learner's preferred type. Imagers performed better than verbalizers in text-plus-pictures conditions, whereas verbalizers performed better than imagers in text-plus-text conditions. However it is not just a question of cognitive style preference. Sutcliffe and Faraday (1994) suggest that different types of media best represent different types of information. A tension exists between the best presentation medium as determined by information type and presentation medium as determined by cognitive style.

The reinforcement and supplementation of information through multiple representations, whether in the same or a different format, also creates a redundancy effect, which aids the process of conceptualization and strengthens the transfer from short-term memory to

long term memory. McAteer and Shaw (1995) state that the more senses that are engaged in learning then the more effective that learning is. Faraday and Sutcliffe (1997) also found that recall improved when information was presented using images and animations as well as with text and speech. Vetere and Howard (1999) draw a distinction between within-channel redundancy, which utilizes the same sensory channel and between-channel redundancy, which utilizes different sensory channels. They found that within-channel redundancy, combining text and audio, leads to better to performance for certain types of tasks. However they also found that within-channel redundancy might at times reduce performance, possibly by inducing cognitive overload.

The use of video and audio may also increase enjoyment and engage a user in a way that static material does not, particularly for school-leavers brought up with ready access to videos and computer games. However this is not a simple relationship. Mayes (1993) reports that the vividness of presentation in itself does not increase the effectiveness of learning and he argues that learners are not easily enticed by the surface aspects of information. Furthermore, the use of dynamic media such as video may get in the way of learning, with not all learners attending to all the multiple representations. Hutchings *et al*. (1993) found that some learners, when using multimedia applications, spent their time solely seeking out the incorporated video clips to the detriment of their learning. Rogers and Sciafe (1997) explore these issues in further depth by examining the most effective way of displaying and co-ordinating multiple representations at the interface. The key to effective learning is to utilize these multimedia elements to motivate a learner into using the application and thence to encourage the hard work needed for real learning.

Delivery control

The non-linearity offered by many multimedia packages allows a user greater navigational control and freedom. Users can decide which sections they wish to visit in an application and in what order. They can control their own pace as they travel through an application, concentrating on material they are unfamiliar with or are particularly interested in and skipping over material they already know or which is irrelevant to their needs at that particular time. Users can also repeat or review sections as needed.

General navigation guidelines are available for a designer of interactive multimedia applications. For example, Fischer (1994) provides advice on how best to guide users through non-linear applications and Davies and Brailsford (1994) advise on the design of navigation and orientation for multimedia learning applications. Kommer *et al*. (1996) provide guidelines for organizing nodes and links as well as advice for user support strategies. The new multimedia standard ISO 14915 has a section on multimedia control and navigation, which describes the different structures which can be used to support navigation as well basic controls for audio-visual media.

Access routes

There are a number of navigation strategies available to designers of interactive learning applications. At one extreme there are resource-based learning environments, for example, hypermedia databases or encyclopaedias, which a user can browse at random. Whilst such artefacts can be a useful teaching resource, in themselves they do not provide a framework in which to learn successfully. Mayes *et al*. (1990) point out that completely free exploration of a network of nodes and links will be sub-optimal for learning. Boyle (1997) echoes this, favouring a more structured learning approach. Ford and Ford (1992) found that some learners become uncomfortable when navigating in hyperspace which in turn can affect performance. McKendree *et al*. (1995) discuss some of the limitations of hypertext and point out that in many instances learners require a narrative-like structure to follow. They also emphasize the importance of engaging the learner in activity, something which a purely resource based approach lacks.

Control of delivery can also be handed over to the application. Such an approach is taken by intelligent tutoring systems, overviews of which can be found in Wenger (1987) and Nwana (1990). Essentially these are computer systems which generate a lesson for an individual learner based on their current state of knowledge. Advice can be given as to different courses of action to take depending on a learner's actions and tutorial support offered. Pang and Edmonds (1999) found that such guided discovery approaches can lead to improvements in learning.

Mayes (1993), however, argues that intelligent tutoring systems promote knowledge acquisition, through helping learners achieve 'mastery' in solving particular problems, rather than helping them come to an understanding of the underlying principles. Intelligent tutoring systems can be seen to be prescriptive, in that the learner has limited control over the presentation of

information. Boyle (1997) further argues that it is difficult to formalize the difference between tutor and learners viewpoints and that at a technical level the intelligent tutoring systems approach is immensely complex. However, intelligent tutoring can offer valuable insights into computer-based learning, which is more widely applicable.

Control should not reside solely with a computer even if a system adapts to the needs of individual learners nor should learners be expected to learn from a completely unstructured environment. A middle ground is needed to promote effective learning. One example is a hierarchical-based menu system where learners can either work through the sections in order but use hyperlinks to explore areas of interest or go straight to a given page when revising. Such an approach provides learners with a framework to navigate within, where they are free to tailor the order in which information is presented to meet their own needs; an environment where a learner can seek information in pursuit of understanding (Mayes, 1993).

Individual preferences

Individual differences can also be provided for within such a framework. Learners can differ in the way in which they prefer to process information. Holism-serialism is associated with a tendency to begin with the whole as against a tendency to approach things in a linear, step by step fashion (Riding and Chema, 1991). Holists tend to adopt a global approach, concentrating on first building a broad conceptual overview into which detail can be fitted, whereas serialists tend to adopt a local learning approach, concentrating on one thing at a time.

Multimedia applications can be structured to provide for both approaches. For example, an application can be divided into sections, with each section starting an overview followed by more detailed explanations. Holists can then start by looking at all the overviews and then return to explore a given section in more depth, whereas serialists can focus one section at a time.

Supplementary information can also be accessed through thematic links, providing background information or analogous material. Links can also be used to clarify information by providing examples and elaboration. Both can help with contextualization and can also encourage exploration and experimentation, thus leading to a deeper understanding of the new material. Thematic linking can also be used to provide alternative viewpoints that may aid the process of reflection.

However, some learners may require help in deciding the most appropriate path through the material and selecting which links to follow. Riding and Sadler-Smith (1992) state that field-dependent individuals tend to organize information into a loosely clustered whole whereas field-independents tend to organize information into clear-cut conceptual groupings. Witkin *et al.* (1977) found that field-independent learners prefer to structure their own learning and are more likely to develop their own learning strategies. Field-dependent learners, on the other hand, may need more assistance in defining problem solving strategies or more exact definitions of performance outcomes. Liu (1994) confirmed this showing that field-dependent learners tended to progress through instructional material following the provided or suggested sequence and that they were less likely than field-independent learners to use index tools and to create their own sequences. Ford (1995) reports that holists also tend to make more use of enrichment material (analogies, illustrations and anecdotes) than serialists. Ford and Ford (1992) also found that not all learners cope successfully when given free choice as to how they access the material. They identified such learners with field dependency, suggesting that perhaps they need more structure and direction than their field independent counterparts.

It appears that field-dependent learners benefit more from explicit orientation than field-independent learners. Anchoring devices or advance organizers can be used to help the field-dependent learner to relate the new material being presented to their previous knowledge. In general, field-dependent learners will benefit from frameworks being provided to lead them through the learning process. Ford (1995) suggests that the form this structure takes can be related to the holist-serialist cognitive style. Further work is needed on how best to do this.

There are two issues that need to be resolved. Firstly, how best to provide for different learning styles when offering advice. One approach is to adapt the advice to a learner's preferences but this requires either online testing to determine what that style was or asking learners which approach they prefer. However, the feasibility of this can be questioned. Such an approach has severe cost implications and, despite advances in computing power, is not likely to be economic in a mass higher education system. Moreover it is also debatable whether such an approach is desirable.

Not only do different students exhibit individual differences in relation to learning but also, as Prosser and Trigwell (1999) argue, the approach taken by a given student depends on the context of that learning and can change over time. Moreover successful learning requires versatility, raising doubt as to the desirability of playing to an individual's strengths. A more learner-centred approach may be to help learners in overcoming weaknesses they may have and so help them become more rounded learners. Presenting individual programmes tailored to an individual is, in effect, taking choice away from that learner. This can hinder the process of encouraging students to develop as autonomous and independent learners.

Educational developers should be aware of the differences that exist and include a variety of different activities and, where possible, offer flexibility. Some students may require guidance in working through the learning material; organizing frameworks and help systems can be useful here.

Further study is needed to determine the best way to ensure that those learners requiring guidance receive it. Our own observations of learners using interactive multimedia learning applications at Napier found that the majority of the learners did not consult the online study guide provided until the end of their first session, if at all. One way round this is to force all learners to view a study guide before continuing with the rest of the application. However this takes control away from a learner and may prove frustrating on subsequent usage. A better approach may be to brief learners prior to using the application, which has the benefit of allowing lecturers to provide other advice tailored to a particular group of learners.

Interactivity

Interactivity in multimedia assisted learning applications can and should go further than simply allowing a learner to choose their own path through an application by pointing and clicking at various menus items and buttons. If deep learning is to be promoted then the application should actively engage the user in carrying out tasks, which allow them to apply the new knowledge being presented. Reflection on that experience needs also to be encouraged. Multimedia affords many opportunities to do this.

Learners can interact with multimedia packages in a number of ways. Learners can manipulate virtual objects on screen and simulations of experiments or industrial processes can also be provided. This allows learners to experiment safely, enabling them to examine the consequences of taking wrong approaches, as well as correct ones, thereby assisting the learner to come to a deeper understanding of the subject. Learners can be supported in viewing the consequences of taking alternative courses of action, which lead to both positive and negative outcomes. Interactivity also supports role-playing, which is useful for language learning or encouraging learners to consider alternative viewpoints. Online testing can be provided, with instant feedback given for learners. The results of these tests can be stored to file and accessed at a later stage by both the learners themselves and staff, allowing progress to be monitored.

A number of applications have already been developed which embody real interactivity, that is interactivity to engage the user in active learning as opposed to interactivity through 'point and click'. Cairncross and Mannion (1999) describe a studio approach to learning applications for engineering, which combines exposition with a virtual experiment. Rogers and Sciafe (1996) report on a virtual ecosystem, *PondWorld*, which can be used by children to find out about food chains. Boyle (1997) describes a number of other such interactive applications. These packages are successful in engaging the learner in activity and are enjoyable to use but there is little empirical data about how effective the learning is. Moreover there are few guidelines for the design of learning activities based on sound educational principles. Aldrich *et al*. (1998) explore the notion of interactivity further and outline the need to identify in a systematic manner those interactivities which support effective learning and those which are largely gratuitous. The key here is to design learning activities which cognitively engage the learner, that is causes them to think about the material that is presented, what it means, its relevance, how it can be applied and in what contexts.

Interactivity can also be used to support synchronous and asynchronous communications between a learner and a tutor or between groups of learners through the agency of electronic mail, bulletin boards and electronic conferencing. This can encourage the learner not only to apply new knowledge being presented to them in discussion with others but also to consider alternative interpretations, helping to clarify any misunderstandings. This process of dialogue encourages reflective thinking and can promote reconceptualization and lead to a deeper understanding of the material being learned (Mayes, 1995). While Smith (1998) points out that such online discussions can lack immediacy, they can also open up new ways of

learning. Vicarious learning can supported, whereby, for example, learners can view the discussions of previous groups studying the same topic and learn from these (McKendree *et al.*, 1997).

Note that such communication with tutors and fellow learners can only be supported in a distributed environment. Self-contained or stand-alone multimedia applications do not provide the opportunity for on-going discussions, although it is possible to provide the answer to frequently asked questions and comments from different sources. Increasingly, however, Internet links are embedded into commercially available CD-ROMs. A similar approach can be taken for bespoke applications. Learners can also be encouraged to pause and reflect on material that has just been presented, by including self-assessment questions.

The potential benefits that multimedia offers educators have been outlined in this section. A range of media elements can be used to convey a given message and learners can control the delivery of that information. Individual preferences can be catered for, through taking advantage of the flexibility that multimedia offers and providing, where appropriate, multiple representations and supporting different access routes. Interactivity can be used to involve the learner in activity, through, for example, providing virtual experiments or quizzes that allow the learner to apply the new material being presented and to test their understanding. Reflection and discussion can also be supported.

INTEGRATION INTO THE CURRICULUM

It is not enough to focus solely on the design of the application. If interactive multimedia is going to be used to its full potential then its integration into the curriculum must carefully be considered. Failure to do so may result in it not being used regardless of how well it is designed. Lecturers wishing to use interactive multimedia to replace some of their teaching should consider carefully how it is going to be used and what support they will make available to learners. One of the perceived benefits of interactive multimedia learning applications is that they allow learners to study at a time and a place convenient to them. However our experience (Cairncross and Smith, 1999) found that learners value personal contact with tutors and other learners and prefer to use such applications in a computer-based tutorial rather than in isolation at home. This is in keeping with another study at Napier (Davidson and Goldfinch, 1998) which found that learners prefer using computer-based learning material in a group with other learners and tutor support than on their own.

This may be because this is a new way of learning for many learners, requiring new ways of working and managing their time. This can lead to resistance from learners. There can also be a slow adaptation process, as learners become familiar with the new technology (Finklestein and Dryden, 1998). Moreover learners are less likely to be receptive to new methods when they are feeling overloaded.

Current thinking also suggests that when evaluating the effectiveness of learning applications that an integrative approach should be taken. Draper (1996, 1997), Gunn (1997), and Milne and Heath (1998) all argue that evaluation cannot be done in isolation through simply looking at the product and that the context in which it will be used must also be considered. This is something that should be borne in mind by researchers when planning trials or interpreting the findings of others. Caution should be exercised when generalizing from laboratory based experimental trials.

CONCLUSIONS

Multimedia can bring a number of advantages to education. The key features of multiple media, user control over the delivery of information and interactivity can help learners come to a deeper understanding through

- supporting conceptualization and contextualization of the new material being presented;
- actively involving the learner in the learning process;
- promoting internal reflection.

Furthermore dialogue between learners and teachers can be supported through combining interactive multimedia with communications technology.

A user-centred approach to the design of multimedia learning applications can be recommended, both from an interactive systems design perspective and also from an educational perspective. This approach should be based on general human–computer interaction principles as well as learning considerations. The key to effective learning is to utilize these multimedia elements to motivate a learner into using the application and thence to encourage the hard work needed for real learning. Contextual factors can impact on this. Theories on how best to realize the benefits outlined

above need to be developed further and then tested. This can help in establishing guidelines to promote successful learning.

Design principles for media selection and presentation at the interface can be strengthened through investigation into the impact on learning of redundancy effects when using multiple representations. More detailed examination is needed on how best to display and co-ordinating multiple representations at the interface.

Interactivity in learning applications merits more detailed investigation and the issue of how best to design learning activities that engage the user needs to be addressed. Additional work is required to determine how best to ensure that learners actually make full use of such features.

Further work also needs to be done to identify suitable learning strategies for effective teaching in an interactive multimedia environment and to match these to individual styles. This can be done by using the flexibility offered by interactive multimedia and allowing the learner to tailor both the presentation of information and access to this, depending on their needs and preferred style. In addition the tension between media selection and access as determined by learning style and determined by information type needs to be resolved.

Guidelines can be strengthened through investigating the effect of differences other than cognitive style, for example gender, age or background, on learning with multimedia applications. More detailed examination into the integration of multimedia into the curriculum and contexts where it has and has not proved effective is also needed.

These guidelines, once developed, can assist the developer of interactive multimedia applications in designing learning material, which promotes enhanced learning for individual learners. Only then will the full potential of multimedia in education be realized.

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